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(54) FUEL INJECTION VALVE ASSEMBLY FOR A RECIPROCATING PISTON INTERNAL-COMBUSTION ENGINE

(71) We, MASCHINENFABRIK AUGSBURG-NURNBURG AKTIENGESELLSCHAFT, a German company of 8900 Augsburg, Stadtbachstrasse 1, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a fuel injection valve assembly for a reciprocating piston internal-combustion engine.

An object of the present invention is to provide a fuel injection valve assembly in which optimal dose determination and intermixing of fuel with air is achieved in all ranges of performance, and in which the fuel does not leak out of the assembly when the valve is closed.

According to the present invention there is provided a fuel injection valve assembly for a reciprocating piston internal-combustion engine, including an injection valve member in the form of a hollow cylinder having at least two annular rows of axially spaced injection bores each extending through the wall of the cylinder, the valve member being axially movably mounted in a recess in an injection valve housing in such a way that the valve member is movable between a closed position in which the injection bores are disposed within the recess and an open position in which at least the downstream ends of the bores are disposed beyond the housing recess thereby to permit fuel to pass therethrough into the region downstream of the injection valve assembly, the valve member being movable to the open position by the supply pressure of the fuel against the bias of a return spring, the valve member being provided with a sealing surface which in the closed position of the valve member abuts a seat on the valve housing thereby to isolate the injection bores from the region downstream of the injection valve assembly.

With a fuel injection valve assembly according to the invention optimal dose determination by the various rows of injection bores, one upon the other, and good intermixing of fuel with air is achieved, in use, for all ranges of engine performance, so that, for example, at low load, e.g. when the engine is idling, only the row of injection bores, which is uncovered first during movement of the valve member from its closed position to its open position, comes into action. As the engine's load increases, the or each further row of injection bores comes into operation at the end of the ignition delay when a certain stroke is completed by the injection valve member. By this means, both rough running and inadequate fuel preparation in the lower and middle range of load is avoided. Furthermore, the injection bores are closed fuel-tight when injection is completed, with the result that no fuel can drip into and contaminate the combustion chamber. This results in turn in good exhaust gas emission and satisfactory specific fuel consumption.

The sum of the cross-sectional areas of the downstream ends of the row of injection bores which is uncovered first is advantageously made smaller in size than the sum of the cross-sectional areas of the downstream ends of the injection bores in the row or rows above it. This form of construction means that the injection quantity can be measured such that at the commencement of the stroke only highly vaporised jets are injected into the combustion chamber with low penetration depth. The result of this is that the quantity of fuel introduced into the combustion chamber during the ignition delay which burns promptly after ignition, is kept small and that without coating the wall of the engine cylinder the jets of fuel pick up the air present near the engine cylinder sleeve

wall and thrust against the main injection which occurs later in time when the larger injection bores in the row or rows above are uncovered.

Conveniently, the injection valve member comprises a cylindrical sleeve loosely mounted on a spindle which is axially movable relative to the valve housing, the valve member in its closed position being pressed against the seat on the valve housing by a spindle head at one end of the spindle by virtue of the return spring acting on the spindle.

Preferably, a brake piston is attached to the spindle, the brake piston being axially movable with the spindle in a bore within the valve housing, which bore communicates with the fuel supply pressure via a restrictor whereby the brake piston is acted upon by low pressure relative to the fuel supply pressure, the brake piston serving to brake the axial movement of the spindle. This brake piston thus controls the rate of movement of the spindle, and in particular the brake piston attached to the spindle prevents the spindle from dropping too quickly. An annular region below the brake piston is filled with fuel which has passed through the restrictor, so that the brake piston with the spindle is retarded, once the brake piston has moved axially sufficiently to close overflow ducts provided in the annular region; the brake piston is immersed in fuel which has leaked through the restrictor.

According to a further advantageous feature of the invention, the pressure of the fuel acting on the brake piston is influenced by a buffer piston upon which a spring acts with a bias which may be modified from outside. Through this, the course of the spindle's rate of movement within specific limits may be influenced. By means of the pressure exerted by the buffer piston, which may be adjusted from outside via an adjusting pin, there arises the possibility of bringing several fuel injection valve assemblies on to equal delivery while idling.

The invention may be carried into practice in a number of ways but one specific embodiment will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a longitudinal section through the lower part of an injection valve assembly according to the invention,

Figure 2 shows a longitudinal section through the upper part of the injection valve assembly according to Figure 1,

Figure 3 shows a diagrammatic representation of a combustion chamber, and

Figure 4 shows a section along line IV—IV of Figure 1.

The lower part of the injection valve assembly 1, illustrated in Figure 1, has an outer screwthreaded sleeve 2 which connects the lower portion 3 of the injection valve housing to the inside wall 5, i.e. the wall facing the combustion chamber 4, of an engine cylinder cover which is not shown in detail. This screwthreaded sleeve 2 is attached by means of a screwthread 6 on its inside wall to an upper portion 7 of the injection valve housing so that the lower and upper portions, 3 and 7, of the valve housing are connected in fuel-tight manner. The upper portion 7 of the valve housing extends with clearance through an opening 8 in the outer wall 9, not shown in detail, of the cylinder cover, an annular sloping shoulder 11 of the screwthreaded sleeve 2 resting in a lower area 10, on a corresponding inclined annular shoulder 12 of the outer wall 8 of the cylinder cover to form a seal. Located in the lower portion 3 of the valve housing on the combustion chamber side, there is a recess 13 into which a hollow cylindrical valve member 14 is loosely and rotatably inserted. This valve member 14 is held in the recess by means of a spindle 15 having a spindle head 16 shaped on its lower end. The recess 13 is connected to a fuel antechamber 18. On the combustion chamber side, the lower portion 3 of the valve housing has an annular sloping seat 19. Abutting this sloping seat 19 when the injection valve member 14 is in the rest position, is a correspondingly inclined sealing surface 20 of the valve member 14, under the bias of a spring 32 active against the upper part of the spindle 15, resulting in a fuel-tight seal.

Located in the injection valve housing 14 are several annular rows of injection bores 21, 22, disposed axially one above the other, the injection bores 21 of the lower row, i.e. the row nearest the combustion chamber 4, being small in diameter than the injection bores 22 of the row above. A possible way of achieving better optimization between idling and full load would be to provide further rows of injection bores between them. The lower row of injection bores 21 is so disposed that it is approximately in alignment with the annular sealing surface 20 of the valve member. The spindle 15 supporting the valve member 14 in its position extends through the central bore 23 of the valve member 14.

Above the fuel antechamber 18 the diameter of the spindle 15 is larger and the central bore 24 of the lower portion 3 of the valve housing through which this larger diameter part of the spindle extends is so sized in diameter that there is formed a restrictor between the spindle 15 and the bore 24. Adjacent its lower end the spindle 15 has an annular rim 25 which fits in the central bore 23 of the member 14 and which

acts as a guide for the spindle 15 in the valve member 14. The central bore 23 of the valve member 14 is in direct communication with the fuel antechamber 18.

Located in the upper portion 7 of the valve housing, likewise penetrated by the spindle 15, is a brake piston 26, rigidly connected to the spindle 15 which defines with its lower edge 27 the top of an annular cavity 28, a circular resilient sealing element 29, provided in the lower portion 3 of the valve housing, defining the bottom of the annular cavity 28. Laterally the annular cavity 28 is limited by a guide member 31 provided in a central bore 30 in the upper portion 7 of the valve housing; the spring 32 is seated on this guide member 31 so that the latter is pressed onto the circular sealing element 29.

The brake piston 26 is constructed adjacent its bottom edge 27 such that a restrictor gap 73 is produced between the guide member 31 and the brake piston 26. Between the brake piston 26 and the spindle 15 there is a sleeve 33 axially located by contact between one end 17 of the sleeve and a shoulder on the spindle 15 so that the brake piston 26 is rigidly connected to the spindle 15. Provided on the brake piston 26 is a further element constructed as a spacer sleeve 34 which is guided for axial movement on the spindle 15. The spacer sleeve 34 has an annular sloping surface 36 in its lower zone 35 and in its upper zone 37 it has a collar 38 for locating the spring 32. In the area of the guide member 31 this spring 32 abuts a spigot 39. Above the spring 32, a ball bearing 40 is mounted on the spacer sleeve 34 on which ball bearing the spring 32 is supported, and seated on this ball bearing 40 is a nut 41 screwed on a screw-thread 42 of the spindle 15; the amount by which the nut is screwed on determines the amount of prestressing in the spring 32. Similarly, the brake piston 26 is rigidly connected to the spindle 15 by securing it between the sleeve 33 and the spacer sleeve 34 with a compressive prestress effected via the nut 41 so that even under the relatively large axial forces occurring in operation mechanical wear of the screwthread on the spindle 15 and of the end 17 of the sleeve 33 which contacts the shoulder on the spindle 15 is reduced to a minimum. A sealing sleeve 43 provided with clearance on all sides ensures a freely movable sliding action of the spindle 15 in the guide member 31 which is axially held between the spring 32 and the circular sealing element 29.

Provided in the upper portion 7 of the valve housing as shown in Figure 1, to one side of the central bore 30, are discrete ducts 44 and 45, of which the duct 44, which affords a fuel supply duct, is connected to a duct 46 running obliquely to the longitudinal axis in the lower portion 3 of the valve housing, the duct 46 terminating at its lower end in the fuel antechamber 18. The other duct 45 is connected via a lateral duct 47 and two smaller overflow docts 48 and 49 to the annular cavity 28.

Figure 2 shows the upper portion 7 of the valve housing continued upwards. In this part of the upper portion 7 a further duct 50 connects to the central bore 30 accommodating the spindle 15. In an upper zone 51, this duct 50 is connected in turn via a lateral overflow duct 52 to a larger bore 53 provided eccentrically relative to the longitudinal axis of the valve housing 7 which is circular in cross-section. There is a further connection in a lower zone 54 with this large bore 53 made by the duct 45 already mentioned in Figure 1, with the result that there are connections between the respective upper regions and the respective lower regions of the bores 30 and 53. Supported in this lower zone 54 is a spring 55 which at its top end bears against a non-return valve member 56 constructed as a ring. Further provided in the bore 53 is a guide sleeve 57 for a buffer piston 58 moving in this guide sleeve 57. This guide sleeve 57 is constructed in two parts, the non-return valve member 56 abutting the lower end of this guide sleeve 57 on a sloping annular edge 59. The buffer piston 58 in turn is supported on an annular, inclined shoulder 74 of the lower part of the guide sleeve 57. An annular cavity 60 is formed between the outer contour of the buffer piston 58, the guide sleeve 57 and the non-return valve 56.

The buffer piston 58 has an inner bore 61 which extends into a blind bore 62 of smaller diameter. The bore 61 is further connected, via lateral overflow bores 63, to an annular cavity 64 in the lower part of the guide sleeve 57, and is covered by means of a bored spring washer 65 which has a spigot 66 engaging in the bore 61. A further spigot 67 projecting in the opposite direction acts as the locating means for the bottom of a spring 68 the top end of which abuts the end of an adjusting pin 69 which is adjustable from the exterior. Via this adjusting pin 69 the prestressing of the spring 68 may be set as required. In the upper zone 51, a screw 70 for venting the assembly is screwed in the wall of the upper portion 7 of the valve housing. The fuel supply duct 44 already referred to in Figure 1 also extends into that part of the upper portion 7 of the valve housing shown in Figure 2.

In Figure 3 there is shown the wall 5, facing the combustion chamber 4, of a cylinder cover which is not otherwise

shown in detail, and a piston, the head 72 of which is curved. As Figure 3 shows, the rows of injection bores 21 and 22 lying one above the other are disposed along the central longitudinal axis A—A. The injection bores 21 of the first or lower row, i.e. that row which is uncovered first when the valve member 14 moves from its closed position (as shown in Figure 1) to an open position in which the downstream ends of the injection bores of all the rows are disposed beyond the housing, are each inclined at an angle α of approximately 75° to 80° to the longitudinal axis A—A of the assembly, the bores diverging relative to the axial direction towards the combustion chamber.

In Figure 4, the injection bores 22 in the upper row are shown. These injection bores 22 are disposed as viewed in the axial direction, tangentially to a circle drawn around the central longitudinal axis A—A of the valve member 14.

During use of the assembly, fuel is conveyed via the fuel supply ducts 44 and 46 to the fuel antechamber 18 to fill the antechamber 18 as well as the central bore 23 in the valve member 14. If the pressure in the fuel antechamber 18 rises, the spindle 15 is moved axially down by pressure on the valve member 14, if the initial stressing force of the spring 32 is exceeded as a result of the pressure operative on the differential area of the recess 13 and the central bore 24. The valve member 14 thereupon moves from the seat 19 on the lower portion 3 of the valve housing, and via the injection bores 21 in the lower row, i.e. the injection bores nearest the combustion chamber, there occurs the preliminary injection. Fuel is thereby conveyed only as far as the vicinity of the wall of the combustion chamber or of the cylinder sleeve without actually coating the wall. By means of the brake piston 26 rigidly connected to the spindle 15, the leakage fuel present in the annular cavity 28 is expelled through the overflow ducts 48, 49 and the restrictor gap 73. By appropriate sizing of the restrictor gap 73, the rate of movement per unit time of the spindle 15 is controlled. All the cavities provided between the brake piston 26 and the buffer piston 58 are filled with low pressure fuel. The brake piston 26 serves for avoiding a jerk downwards by the spindle 15 and with it the valve member 14 and preventing the brake piston 20 striking against the circular sealing element 29, as well as ensuring that the main injection only takes place when the temporary ignition delay has passed. The leakage fuel in the annular cavity 28 thus acts as a cushion for the brake piston 26. The annular cavity 28 is always filled with leakage fuel as at every stroke movement of the spindle 15 via the bore 24 a small quantity of fuel is conveyed into this annular cavity 28. The leakage fuel expelled by this brake piston 26 escapes out of the lateral overflow ducts 48 and 49 into the duct 45 and from there into the lower zone 54 of the bore 53.

During the preliminary injection through the injection bores 21 the valve member 14 is set in rotation. This is caused by virtue of the injection bores being disposed tangentially as shown in Figure 4, by reaction to the force of the fuel jets. The spindle 15 is also set in rotation by means of friction between the valve member 14 and the spindle head 16. The sealing sleeve 43 provided with clearance on all sides ensures free movement of the spindle 15 with the lowest possible leakage from the annular cavity 28, with the result that after closure of the overflow ducts 48 and 49, the spindle 15 can rotate between a hydraulic thrust bearing, formed between the brake piston 26 and the circular sealing element 29, and the ball bearing 40. Only after completion of the ignition delay when a certain stroke has been completed by the spindle 15, do the larger diameter injection bores 22 in the upper row come into action and the main injection commences. Through this principle both rough running and inadequate fuel preparation in the lower and middle operating range of load can be avoided. The emission of exhaust may thereby be improved considerably. Since the injection bores 21 and 22 of the valve member 14 may be closed fuel-tight by the seat 19 and the annular sealing surface 20 of the valve member 14 after injection, contamination of the combustion chamber is also avoided.

During the rotation of the valve member 14, the fuel jets issuing from the bores sweep over the entire annular region of the combustion chamber 4 inside the cylinder sleeve, resulting in a good intermixing effect. At the same time, in addition to the rotation initiated by the injection through the bores 21 during the preliminary injection, the jets also create turbulence in the combustion chamber 4 and owing to the inclination of the injection bores 21 to the central longitudinal axis A—A at approximately 75° to 80°, by causing the main air to circulate in the area between the cylinder sleeve, the cylinder cover 5 and the piston head 72, as shown in Figure 3. The main injection via the injection bores 22, which occurs after the air turbulence forms during the ignition delay, is directed near to the cylinder cover 5 in a direction opposite to the air flow direction in that region. This means that in terms of time rapid intermixing of fuel and combustion air takes place and that the air near the cylinder sleeve is conveyed towards the fuel

jets of the injection bores 22. Complete combustion at full load where with a small ignition delay the combustion of the fuel would already commence soon after its exit from the injection bores if there is sufficient oxygen present, may here be achieved, while simultaneously reducing the duration of combustion.

The means of setting several fuel injection valves to the same injection quantity is the buffer piston 58 with the spring 68 whose prestressing may be set as required from outside via the adjusting pin 69. Via the pressure in the bore 45 which may thereby be varied, to the counter pressure for the overflow ducts 48 and 49, the rate of movement of the spindle 15 may be influenced within specific limits. The pressure building up in the lower zone 54 of the bore 53 has the effect that the buffer piston 58 moves upwards against the force of the spring 68. In the course of this movement, the buffer piston 58 rises from the inclined shoulder 74 of the lower part of the guide sleeve 57 and thus frees the path of the leakage fuel from the cavity of the buffer piston 58 via the overflow ducts 63 and the annular cavity 64 to the cavity 60. If the lower region 54 of the bore 53 is only partially filled with leakage fuel, the pressure in the cavity 60 becomes greater and the non-return valve 56 opens against the force of the spring 55, resulting in leakage fuel penetrating into the lower region 54 of the bore 53 and thus being able to fill up this region. If the lower region 54 is full, however, no leakage fuel will be able to flow as the pressure in this region will be greater than in the cavity 60 and the non-return valve 56 would not open. The leakage of the fuel present in the duct 45 and the annular cavity 28 is thus conveyed back again via the non-return valve 56, so that after injection has occurred, this duct 45 and the annular cavity 28 are always completely filled again. This is a necessity as the annular cavity 28 must always be filled with leakage fuel since otherwise sufficient suppression or slowing down of the brake piston 26 does not occur.

WHAT WE CLAIM IS:—

1. A fuel injection valve assembly for a reciprocating piston internal-combustion engine, including an injection valve member in the form of a hollow cylinder having at least two annular rows of axially spaced injection bores each extending through the wall of the cylinder, the valve member being axially movably mounted in a recess in an injection valve housing in such a way that the valve member is movable between a closed position in which the injection bores are disposed within the recess and an open position in which at least the downstream ends of the bores are disposed beyond the housing recess thereby to permit fuel to pass therethrough into the region downstream of the injection valve assembly, the valve member being movable to the open position by the supply pressure of the fuel against the bias of a return spring, the valve member being provided with a sealing surface which in the closed position of the valve member abuts a seat on the valve housing thereby to isolate the injection bores from the region downstream of the injection valve assembly.

2. An injection valve assembly as claimed in Claim 1, in which the sum of the cross-sectional areas of the downstream ends of the injection bores in the annular row which is uncovered first during movement of the valve member from its closed position to its open position, is smaller than the sum of the cross-sectional areas of the downstream ends of the injection bores of the or each other annular row.

3. An injection valve assembly as claimed in Claim 1 or Claim 2, in which the downstream ends of the injection bores in the annular row which is uncovered first during movement of the valve member from its closed position to its open position are disposed immediately upstream of the sealing surface of the valve member.

4. An injection valve assembly as claimed in any one of the preceding Claims, in which, as viewed in the axial direction, the injection bores extend through the wall of the cylindrical injection valve member tangentially to a circle drawn around the axis of the injection valve member.

5. An injection valve assembly as claimed in any one of the preceding Claims, in which the injection bores in the annular row which is uncovered first during movement of the valve member from its closed position to its open position are each inclined to the central axis of the valve member at an angle of approximately 75° to 80°, the said injection bores diverging relative to the axial direction towards the region downstream of the injection valve assembly.

6. An injection valve assembly as claimed in any one of the preceding Claims, in which the interior of the valve member communicates with a fuel antechamber located in the injection valve housing upstream of the valve member.

7. An injection valve assembly as claimed in Claim 6, in which the fuel antechamber is in communication with a fuel supply duct extending within the injection valve housing.

8. An injection valve assembly as claimed in any one of the preceding Claims, in which, the injection valve member comprises a cylindrical sleeve loosely

mounted on a spindle which is axially movable relative to the valve housing, the valve member in its closed position being pressed against the seat on the valve housing by a spindle head at one end of the spindle by virtue of the return spring acting on the spindle.

9. A injection valve assembly as claimed in Claim 8, in which a brake piston is attached to the spindle, the brake piston being axially movable with the spindle in a bore within the valve housing, which bore communicates with the fuel supply pressure via a restrictor whereby the brake piston is acted upon by low pressure relative to the fuel supply pressure; the brake piston serving to brake the axial movement of the spindle.

10. An injection valve assembly as claimed in Claim 9, in which the pressure of the low pressure fuel acting on the brake piston is influenced by a buffer piston axially movable in a further bore within the valve housing, which buffer piston is acted upon by a prestressing spring the spring force of which is adjustable by adjusting means which is adjustable from outside the injection valve assembly.

11. An injection valve assembly as claimed in Claim 10, in which the injection valve housing has a generally circular cross-section, the bore which accommodates the brake piston and the spindle being centrally disposed in the valve housing, and in which the further bore accommodating the buffer piston is disposed eccentrically in the valve housing.

12. An injection valve assembly as claimed in Claim 10 or Claim 11, in which the bore accommodating the brake piston and the further bore accommodating the buffer piston are in communication via ducts within the valve housing whereby the regions in the said bore and the said further bore above the respective brake and buffer pistons are in communication and the regions below the brake and buffer pistons are in communication.

13. A fuel injection valve assembly substantially as specifically described herein with reference to the accompanying drawings.

14. A reciprocating piston internal-combustion engine having a fuel injection valve assembly as claimed in any one of the preceding Claims.

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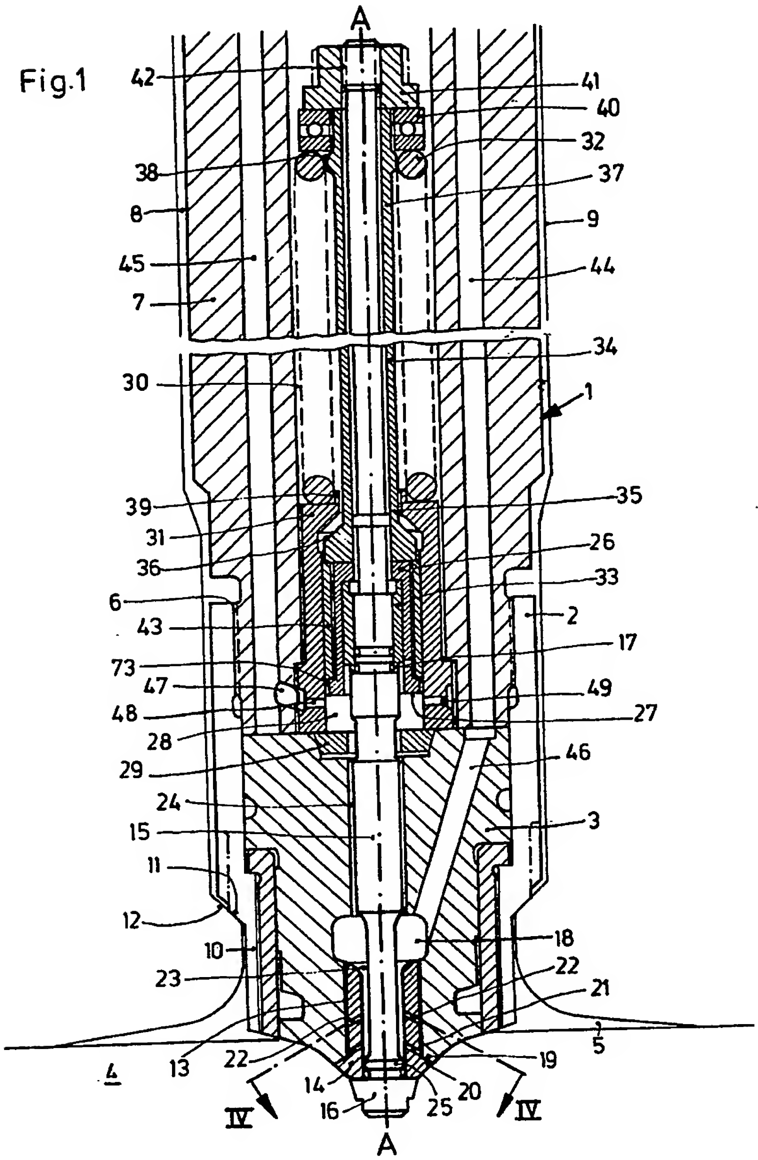
Fig.1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1521065 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

Fig. 2

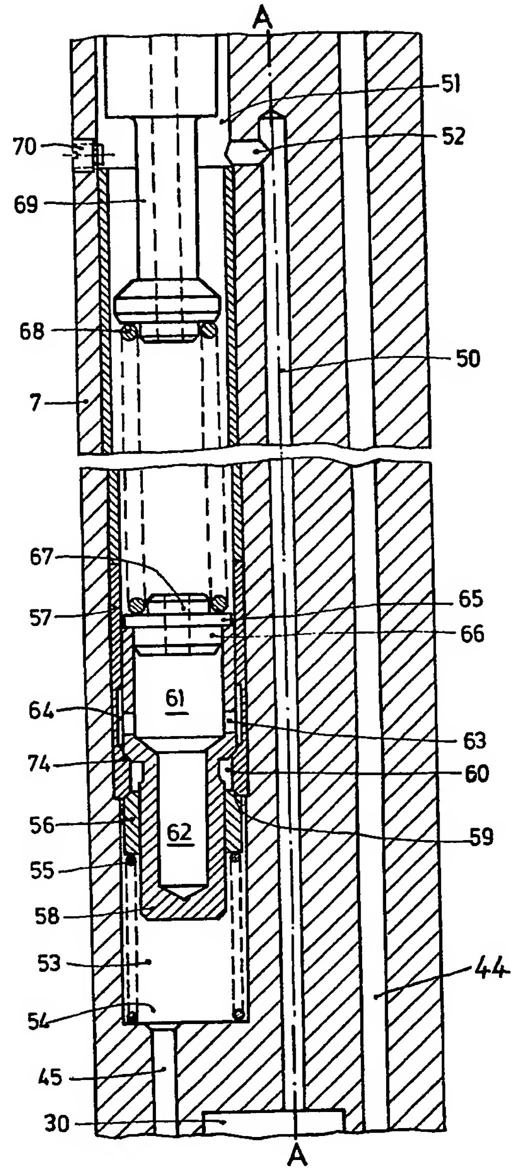
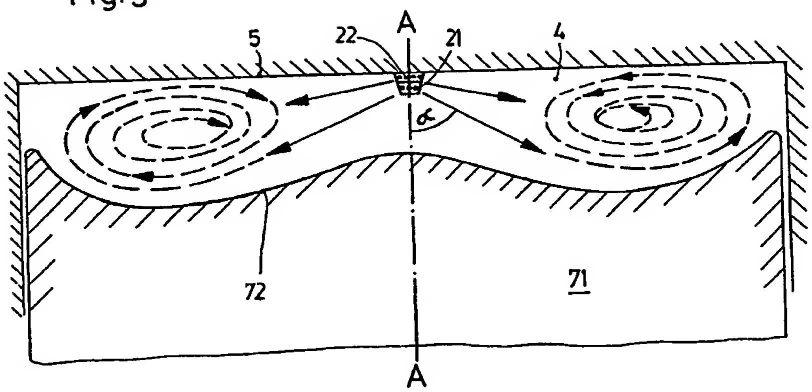


Fig. 3



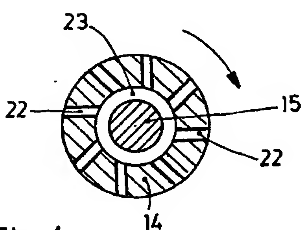


Fig. 4